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THERMODYNAMIC THEORY FOR SIMPLE AND COMPLEX DISSIPATIVE STRUCTURES

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ABSTRACT

Dissipative structures (DS) are at all scales, systems, and at different levels of complexity; but have a common base in non-equilibrium thermodynamics. This conceptual study integrates simple and complex DS by addressing existence of growing or decaying DS from entropy-based analysis (considering mass energy-exchange by DS with surroundings). Two entropy-based dimensionless ratios are introduced that explain negentropy debt payment and existence of DS with growth / decay:

I. Dimensionless ratio of release-flow to in-flow entropy rates of growing and decaying DS is, $\Pi_{\mathrm{S,rel/in}} = \left[\frac{\dot{S}_{\mathrm{rel,tot}}(t)}{\dot{S}_{\mathrm{in,tot}}(t)}\right]$ (> 1, from 2nd Law); hence, ($\Pi_{\mathrm{S,rel/in}} - 1$) is a measure of, "excess negentropy-debt paid" due to DS-existence. Difference between release-flow and in-flow entropy rates is the entropy rise rate of the surroundings ($\dot{S}_{\mathrm{sur-DS}} > 0$, from 2nd Law), which is the excess "*negentropy-debt*" paid to surroundings due to DS-existence. Negentropy-debt is paid by: (*i*) growing DS using mass-energy content of its surroundings (it is needed for DS growth and is beneficial for DS-existence); (*ii*) decaying DS using part of its own mass-energy content in release-flows (it is counter-productive to DS, as it hastens approach to DS perish).

II. Entropy change rate of DS can vary due to, change in its disorder-level, $\dot{S}_{\mathrm{DS,org}}$, and accumulation of mass-energy content in DS, $\dot{S}_{\mathrm{DS,acc}}$. Entropy-based dimensionless ratio, $\Pi_{\mathrm{DS,acc/org}}$ (= $\dot{S}_{\mathrm{DS,acc}}/\dot{S}_{\mathrm{DS,org}}$), determines growth (sustained / un-sustained) and decay (gradual / rapid), of DS. Growing complex DS pay lesser negentropy debt due to involvement in several other activities that are enabled by their complexity, leading to, $\dot{S}_{\mathrm{DS,org}} > 0$. Mediation is one of the main factors augmenting complexity, but it is needed for survival that is linked with mortality of complex DS; hence, complex DS can enter decay-phase also due to increase in their $\dot{S}_{\mathrm{DS,org}}$. Therefore, disorder of complex DS increases and their growth can be un-sustained, leading to entry in decay-phase, in spite of availability of adequate mass-energy in-flows. Reduction in complexity or proper management of complexity can enable increase in both $\Pi_{\mathrm{S,rel/in}}$ and $\Pi_{\mathrm{DS,acc/org}}$ (in the direction of ideal growth, $\dot{S}_{\mathrm{DS,org}} = 0$). Prolonged existence of DS is either in the sustained growth or gradual decay phase, as other two phases (un-sustained growth, rapid decay) are relatively much shorter.

As part of future research scope, above claims can be taken forward to study entropy production ($\dot{S}_{\mathrm{gen}}$) by DS collectively, for comparing global $\dot{S}_{\mathrm{gen}}$ with individual $\dot{S}_{\mathrm{gen}}$ when operating in group.

Keywords: complexity, dissipative structure, entropy-energy ratio, negentropy debt

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